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## ABSTRACT

A series of experiments investigated infants' perception of inherent structural organization in the prosody of utterances. The experiments used a listening preference procedure to test: perceptions of appropriate pauses in child-directed and adult-directed speech; perceptions of appropriate pauses in speech filtered for most segmental features but leaving prosodic features intact; and the role of experience in infants' sensitivity to prosodic cues and clausal units, by exposing the native English-speaking children to Polish speech. Infants in the English-language experiments were aged 6 to 12 months, and the infants in the Polish-language experiments were aged 4-and-a-half and 6 months. The study presents results and discusses them in relation to research on children's perceptions of music. (MSE)

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Perception of cues to clausal units in native and non-native  
languages

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The infant attempting to learn language is faced with a wide variety of problems. One of these concerns the way in which the native language uses sounds to designate objects and events in the world. Learning this entails knowledge about the way that the language structures both sounds and meanings. At the level of meanings, the child must discover the way in which the meaning units in the language encode the objects and events that he or she experiences. At the level of sounds, the child must determine the elementary acoustic units and the permissible combinations that can be used to designate meanings in the language. All of this is complicated by the fact that speech occurs in a continuous stream, as opposed to a sequence of discrete units (e.g. Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). Hence, an important pre-requisite for this process is the ability to segment speech into appropriate units within the native language.

Just what are the appropriate units? At one level, words, or morphemes, are because they would seem to be the building block of sentences within the language. However, to communicate effectively it is necessary to master the way that words themselves are organized into units at the level of phrases and clauses. Hence, the child needs to have a means of determining how sounds are packaged into such higher level units such as phrases and clauses. A faulty segmentation of utterances whereby part of one clause is grouped with a part of another clause would not permit the listener to recover the speaker's intended meaning. One approach to segmenting speech into clausal units might be to use pauses found in utterances as indicators of such units. However, pause structure is not a completely reliable indicator of clausal units in fluent speech. Utterances may be produced with little in the way of pausing between successive clauses and, alternatively, pausing may occur internal to clauses (e.g. Cooper & Paccia-Cooper, 1980). However, pause structure in combination with other kinds of prosodic cues may provide an initial marking of speech into units such as clauses. In particular, it has been noted that, in adult speech, changes in fundamental frequency and syllable duration also tend to be correlated with clausal boundaries (e.g. Luce & Charles-Luce, 1983; Streeter, 1978). Moreover, perceptual studies indicate that adults' decisions about units in utterances are influenced by changes in intonation and syllable duration (Scott, 1982; Scott & Cutler, 1984). Therefore, there is some evidence that

prosodic cues may play a role in the way in which adults segment speech into clausal units.

Studies such as these form the background to our own investigations concerning whether infants are sensitive to prosodic markers of important linguistic units such as clauses. One reason for believing that such cues might be important for infants is the fact that prosodic variables tend to be exaggerated in child-directed speech (Bernstein-Ratner, 1985; Broen, 1972; Fernald, 1984; Morgan, 1986). Moreover, it has been shown that infants are more attracted to the exaggerated prosody of child-directed speech in comparison to adult-directed speech (Fernald, 1984). Our interest was to establish whether the prosody of child-directed speech might provide infants with perceptual packages that correspond more or less to clausal units.

The manner in which we have approached this problem is to explore whether the infant experiences any inherent structural organization in the prosody of utterances. In other words, does the infant's perception of prosody provide him or her with information that some points afford a more natural stopping place than others in the flow of speech. If infants are sensitive to prosodic packaging of clausal units, then introducing an artificial pause after the end of a clausal unit might seem more natural than one that appeared between two words in the middle of a clause. We label the first type of materials as Coincident samples and the second type as Noncoincident samples. In keeping with our hypothesis that the prosodic markers might be more prominent in child-directed speech, we obtained our speech materials from a mother talking to an 18 month old infant. We selected 16 passages that included 5 or 6 clauses, digitized the samples, stripped them of any existing pauses longer than 450 ms, and then created pairs of samples by inserting 1 sec periods of silence either at the end (Coincident samples) or in the middle (Noncoincident samples) of each clause in the sample. Besides the pause location, the only other difference between the two samples was that the text of the Noncoincident samples started two or three words before or after the Coincident ones and ended two or three words before or after it.

To explore infants' responsiveness to the two kinds of samples, we adapted the listening preference procedure used by Fernald (1984). Testing takes place with the infant seated on the parent's lap in the middle of a three-sided white pegboard enclosure, four by six feet on three sides and open at the back. A white curtain extending to the ceiling surrounded the three sides of the enclosure. On the center wall at midline facing the child is a green light. A red light is mounted at eye level on each of the side panels 78 degrees to the left and right of the infant when facing midline. In addition, a loudspeaker is mounted behind the panel just below the red light on each side. An observer is seated behind the center panel with a response box on her lap. The response box is connected to a LSI 11/73 computer. The box is equipped with a series of buttons that start and stop the flashing center and side lights, record the direction and duration of a headturn and terminate a trial when the infant looks away for more than 2 sec.

An experimental session with each infant includes both an 8-trial pre-exposure phase and a 12-trial test phase. For each infant, Coincident samples consistently occur on one side of the test booth, and Noncoincident samples on the other side. The pre-exposure phase is designed to acquaint the infant with the assigned position of each type of sample (for details see Hirsh-Pasek et al., 1987). During the test phase, the green light at center flashes to attract the infant's attention. Once the infant is oriented at midline, the observer presses a button on the response box and one of the two red sidepanel lights begins to flash. Which one flashes is determined by the computer according to a random sequence<sup>1</sup>. When the infant orients in the direction of the light (by at least 30 degrees from midline), the observer presses another response button which activates the speech sample appropriate to that side. Whenever the infant fails to maintain the 30 degree

<sup>1</sup>The procedure described here is a slightly modified version of the one that we used in our previous studies (Hirsh-Pasek et al., 1987; Kenler Nelson et al., 1989). The change is that under the prior procedure, the infant actually chose, by turning to one side or the other, which type of sample, Coincident or Noncoincident would be played on a given trial. Under the new procedure, the computer makes the selection. This change allows us to measure each infant's response to both versions, Coincident and Noncoincident, of each sample. It also ensures that infants will be exposed to equal numbers of Coincident and Noncoincident samples. Because data about which side the infant turned to most often was not informative in the earlier experiments, we felt that the change was warranted.

headturn, the observer presses a response key. If the duration of the infant's headturn away from the speaker exceeds 2 sec., the computer terminates the sample. Otherwise it is played in its entirety. Information about the duration of the infant's orientation times to each sample is stored on the computer. During the course of the 12 test trials, the infant is exposed to 6 Coincident versions of samples and their respective Noncoincident versions. The ordering of the samples is pseudorandom with the constraints that both versions of a particular sample do not occur on successive trials nor are there runs of more than two samples of the same type, Coincident or Noncoincident. Because the pairing of the samples, Coincident or Noncoincident, with side, left or right, is determined by computer, the observer is blind with respect to this information. In addition, both the observer and parent wear acoustically sealed headphones and listen to recorded music to prevent them from hearing the samples.

The results of our first study with this method indicated that American infants 6- to 10-months of age are sensitive to the prosodic correlates of clausal structure in English (Hirsh-Pasek et al., 1987). Thus, the average orientation times for the Coincident and Noncoincident versions were 8.1 sec. and 6.3 sec., respectively. All told, 19 of 24 infants tested had longer orientation times for the Coincident versions. Moreover, looking across the test sample pairs, the Coincident version received longer orientation times in 11 of 12 cases.

In a follow-up study, we decided to explore the extent to which the exaggerated prosodic packaging of child-directed speech might provide the infants with salient marking of the clausal units (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989). For this purpose, we invited back the mother who had produced our original recordings and recorded her in conversation with a college student. We used these materials as before to produce a series of samples with Coincident and Noncoincident versions of each. Thirty-two 7- to 10-month old infants were tested; 16 of the infants heard the adult-directed speech samples, and 16 heard the child-directed samples used in the earlier study. Our results supported the view that child-directed speech may provide a more salient marking of clausal units for infants. Specifically, the differences in the infants' preferences for the

Coincident samples were greater for child-directed speech than they were for adult-directed speech. In fact, only in the case of the child-directed speech was there evidence of significantly longer orientation times to the Coincident samples. For this reason, we have continued to use child-directed speech samples in subsequent investigations that we have conducted.

Although our supposition was that preferences for the Coincident versions of the samples were based on prosodic cues, our samples did contain other information that might be pertinent even at this young age. For example, information about phonetic segments is also available in the stimuli. It is known that different allophones (variants) of the same phoneme are often severely constrained according to the position in which they can appear within a syllable (e.g. Church, 1987). Similarly, restrictions (phonotactic constraints) exist on the allowable sequences of phonemes that a language permits within a word or syllable. Thus, whereas Polish permits sequences like [kt] and [db] to begin a word, such sequences occur in English only when they belong to two different syllables. Finally, the presence of phonetic segments allows for the possibility that the infant recognizes the presence of certain words in the input. Thus, it is possible that the infant has already developed some knowledge about the appearance of such words and where they are likely to occur with respect to a pause. For example, a pause in English after the words, "the" and "a", is highly improbable. Although we viewed it unlikely that segmental information of these sorts contributes in a significant way to identifying clausal units, especially at this age, we could not rule it out.

For this reason, we decided to conduct an experiment using materials which remove most of the segmental features from our samples. We low-pass filtered our child-directed speech samples at a level (400 Hz) which left the prosodic information intact but made the identification of segments almost impossible. We then played these filtered stimuli to a group of twenty-four 6-month-olds. Once again, a clear preference emerged for the Coincident versions of the samples. The mean orientation times were 7.09 sec. for the Coincident versions and 5.83 sec. for the Noncoincident versions ( $t(23) = 3.70, p < .005$ ). Overall, 19 of the 24 subjects had longer orientation times to the Coincident versions and across the sample pairs, the Coincident

version was preferred in 10 of the 12 cases. Thus, the results indicate that the same pattern of preferences for speech segmented into clausal units (i.e., the Coincident versions) holds even when the infants must rely on prosodic, rather than segmental, cues. This result supports the view that sensitivity to prosodic markers can provide the infant with information about clausal units.

Another question of great interest to us in our explorations of the potential role of prosodic markers in language acquisition, concerns the contribution of experience in utilizing such cues. In particular, one can ask whether American infants' sensitivity to prosodic markers of clausal units is the result of their specific experience with native language strings during the first half year of life. For instance, they may have detected a tendency in English for pausing to be preceded by accompanying changes in fundamental frequency and syllable duration. Thus, experience with input from the native language may be primarily responsible for the infant's sensitivity to prosodic markers in the language. Alternatively, a more general type of experience *any* language may be sufficient to develop sensitivity to prosodic markers in some other language. Finally, the role of experience may be minimal. Instead, the infant may be innately predisposed to look for such relations when listening to speech in any language. Such a predisposition would be reasonable to the extent that different languages mark important boundaries in the same way. In fact, there is some evidence that a terminal fall in intonation coincides with the ends of declarative utterances across a wide range of languages (Bollinger, 1978). In addition, there is some evidence that adults are sensitive to speech cues correlated with clausal units in unfamiliar foreign languages (Pilon, 1981; Wakefield, Doughtie & Yom, 1974).

To investigate the role that experience plays in the infant's sensitivity to prosodic cues to clausal units, we decided to explore their responses to utterances in a foreign language. The language that we chose to present to our American infants was Polish. It has a number of desirable properties from our point of view. First, it is one of the languages that Bollinger (1978) identified as employing a terminal fall in intonation. Second, unlike English which employs word order to encode important syntactic relations in utterances, Polish uses a case system to encode such relations. Thus, it allows

for a free word order. This property of the language should prove especially interesting for future investigations of subclausal units, such as phrases. Finally, the language was familiar to one of us -- a critical point for ensuring the correct insertion of the pauses into the test samples.

A Polish woman who had recently settled in the U.S. came into the laboratory with her 18 month old child and was recorded interacting with her. As in our earlier studies, passages consisting of 5 or 6 clauses were digitized, with natural pauses longer than 450 ms removed, and 1 sec. silent intervals inserted at either clause boundaries or within clause locations to produce the Coincident and Noncoincident versions of each sample. Four of the sample pairs were used for the pre-exposure trials and the remaining 12 were used for the test trials.

Twenty-four 6 month old infants were tested on the Polish samples. The average orientation times were 6.2 sec. for the Coincident versions of the samples and 6.41 sec. for the Noncoincident versions. This difference was not significant ( $t(23) = -0.44$ ). Overall, 13 of the infants had longer orientation times to the Coincident versions and 11 to the Noncoincident versions. Thus, there was no indication that 6 month old American infants were sensitive to prosodic markers of clausal structure in Polish utterances.

There are several possible explanations for this result. First, it may be that some experience listening to a particular language is necessary in order to detect prosodic markers of clausal units. Second, it is possible that, contrary to our expectations, the Polish samples did not contain any consistent prosodic marking of clausal units. However, this possibility was ruled out when we tested a group of 12 American adult subjects with the Polish sample pairs. For each Coincident/Noncoincident pair, we asked the subjects to select the one that sounded most "natural". The Coincident version was selected significantly more often (about 76% of the time). Next, we low-pass filtered our speech samples at 400 Hz to remove all distinctive phonetic information. This process left only the prosodic information intact for the samples. Under these conditions, subjects still selected the Coincident version significantly more often (about 75% of the time). This suggests that

there is sufficient information in the prosody to distinguish the two versions of the samples.

Finally, a third possibility is that the infants are sensitive to prosodic marking of clausal units in Polish, but they were distracted by the unfamiliar phonetic and phonotactic structure of the language. If this distraction were removed, they might respond to the prosodic markers. In order to evaluate this possibility, we prepared low-pass filtered versions of our Polish samples. Twenty-four 6-month-olds were tested with these samples. Once again there was no evidence of significant differences in orientation times to the two types of samples. The mean orientation time for the Coincident versions was 8.66 sec., whereas for the Noncoincident versions, it was 7.97 sec. ( $t(23) = 0.97$ ). Half of the subjects had longer orientation times for the Coincident versions, and the other half for the Noncoincident versions. Thus, it appears that the lack of a significant preference for the Polish Coincident samples on the part of American 6-month-olds is not solely attributable to their being distracted by the phonetic and phonotactic structure of the language. Nevertheless, the phonetic and phonotactic structure of the Polish samples does seem to affect the 6 month olds' orientation times. Specifically, the orientation times were longer for the filtered versions of the samples. This was verified by an ANOVA comparing the orientation times to the filtered and unfiltered versions of the samples. The only significant effect observed was a main effect for filtered versus unfiltered samples ( $F(1,92) = 11.66, p < .001$ ).

Could it be that some familiarity with a language is necessary to detect any kind of phonetic marking of clausal units that might be present? Or, is there some other alternative explanation for the results that we obtained? One possibility we entertained was that, by 6-months of age, infants may be so attuned to the sound patterns of their native language that they might not attend to ones from foreign languages. In other words, the infant may attend carefully to the specific characteristics of the prosody in the native language at an early age and, in the process, become less sensitive to characteristic prosodic patterns in other languages. Although it might seem surprising that infants become focused on features of the native language so early, a process of this sort is believed to occur for the perception of phonetic contrasts

around 10 months of age, when a prior ability to discriminate certain contrasts in non-native languages appears to drop out (Werker & Tees, 1984; Werker & Lalonde, 1988; cf. Best, McRoberts & Sithole, 1988). Moreover, it has been shown that sensitivity to prosodic characteristics of the mother's native language is present in infants shortly after birth. Thus, Mehler, Jusczyk, Lambertz, Halsted, Bertoncini and Amiel-Tison (1988) found that 4-day old infants showed reliable preferences for utterances from the mother's native language versus ones from a foreign language, even when these were low-pass filtered to leave only the prosody intact. In contrast, when the comparison involved utterances from two foreign languages, there was no evidence of reliable preferences at this age, nor later at 2-months of age. These results suggest that infants may rapidly lock in to the prosodic characteristics of the native language.

To explore this possible explanation of our results, we decided to test infant's at a younger age. One limiting factor that we faced was that our preference procedure can be used only with infants as young as 4 1/2 months of age. Head control in infants younger than this is not sufficiently well established to permit them to be tested using this method. Because we had not tested infants this young before even with English utterances, we decided to test two groups of infants: one with the English samples and the other with the Polish ones. Twenty-four 4 1/2 month olds were tested on each type of sample. The results indicated that for both languages, there was a significant preference for the Coincident versions of the samples. For the English samples, the mean orientation time was 7.52 sec. for the Coincident versions and 5.68 sec. for the Noncoincident ones. For the Polish samples, the respective means were 10.21 sec. and 7.68 sec. An ANOVA of a 2 (Language: English vs Polish) by 2 (Sample type: Coincident vs Noncoincident) indicated significant main effects for both Language ( $F(1,46) = 13.60, p < .01$ ) and Sample type ( $F(1,46) = 31.33, p < .01$ ) and no significant interaction between these two factors ( $F(1,46) = 1.05$ ).

For us, the important result is that, at 4 1/2 months of age, American infants do display a reliable preference for the Coincident versions of the Polish samples. Thus, during the earliest stages of development, a period of familiarization with a specific language is not necessary for the infant to

respond to prosodic markers of clausal units in that language. Rather, the infant appears to be predisposed to respond to certain relations among the prosodic features in the input. Predispositions of this sort may provide the infant with an initial means for segmenting the input pending refinement based on a more detailed assessment of prosodic structure of the native language. The main effect of language, in which infants listening to the Polish stimuli had longer orientation times overall than those listening to the English stimuli, may be an indication that the infants detected something unfamiliar about the utterances.

A natural question to ask at this point is, what cues are infants relying on for information about the likely segmentation of the input? As noted earlier, Bollinger's (1978) survey of different languages suggests that a terminal fall in fundamental frequency often accompanies boundaries in declarative sentences. We are in the process of analyzing the utterances used in our studies to determine the extent to which this pattern holds for our Polish and English samples. In the meantime, some results from a related series of studies that Carol Krumhansl and I (Krumhansl & Jusczyk, 1989) have been carrying out with musical stimuli may provide some insights into the cues to which infants may be responding.

Music shares with speech the characteristic of being hierarchically organized into units of varying temporal extents (Lerdahl & Jackendoff, 1983; Meyer, 1973). Moreover, like speech, musical pieces tend to be organized into segments such as phrases. For adult listeners, the perceptual segmentation of music into such phrases has been shown to depend on both rhythmic and pitch structures, including melody and harmony (Palmer & Krumhansl, 1987 a,b). To investigate the extent to which infants, too, might be sensitive to phrase structure in music, Krumhansl and I conducted a study similar to the ones reported here for language. We selected simple musical pieces, Mozart minuets, and inserted two-beat pauses (approximately 1 sec.) either at phrase boundaries or in the middle of the phrases. We obtained evidence of significant preferences in infants as young as 4 1/2 months of age for samples in which the pauses coincided with the musical phrase boundaries. In other words, the music results parallel those with Polish and English samples at 4 1/2 months of age. More important, we

were able to determine the musical correlates of the orientation time differences. Two musical variables were strongly correlated with the tendency for infants to orient longer to the Coincident samples. These were the pitch duration and pitch height of the last tone prior to a pause. In particular, the Coincident samples tended to have a sharp drop in pitch height and an increase in pitch duration in the tone immediately preceding the pause. These tendencies were not present for the tone immediately preceding the pause for the Noncoincident samples. Remarkably, these two cues, a drop in the melodic line and an increase in the duration of the final tone, appear to parallel directly the terminal fall and syllable duration cues that have been suggested as prosodic markers of clausal units. One implication of these results is that, at an early stage of development, the segmentation of speech and musical sequences may have a common perceptual origin. This would fit with the view that at the earliest stages, sensitivity to prosodic markers in speech is not confined to the native language.

A remaining puzzle is why sensitivity to prosodic marking of clausal units drops out between 4 1/2 and 6 months. We can only speculate as to what the reason may be. First, it is not clear how general the insensitivity is to foreign languages because we only have data on one case so far. It may be that, as in the case of phonetic contrasts (e.g., Best et al., 1988), sensitivity remains high in some cases but not others. Second, we note that the insensitivity to such prosodic marking in foreign languages is not a permanent one. Adults *do* demonstrate sensitivity to such markers in unfamiliar foreign languages as our results and others (e.g., Pilon, 1981; Wakefield et al., 1974) have shown. Thus, one suggestion is that the insensitivity that appears in the 6 month old infants is a temporary one brought on by special demands of the language learning process. In particular, this period of time coincides with the onset of babbling behavior. It may be that the tendency to focus so closely on the specific characteristics of the native language comes about as the infant attempts to match his or her vocal output with that of adults. One would expect that this focus on the native language may continue, perhaps even for several years, until the infant attains some reasonable proficiency in producing utterances that conform to its phonology.

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